PREFACE -- NOTE TO THE READER

I consider the following chapter, reprinted from the The New Papyrus, Published by the Microsoft Press, Redmond Washington, 1986 seminal to my thinking about the potentials of the new emerging interactive multi-mediated technologies of today. Though the chapter was written before the emergence of hypertext and hypermedia, the vision articulated in these remarks ais not only current but charters a future potential for the next decade. ---In this respect, CD-ROM is a guiding metaphor for our deliberations as the storage systems increase in density and navigation tools become more powerful and transparent as we enter the age of the superdata and information highway.

Gabriel Ofiesh.

THE SEAMLESS CARPET OF KNOWLEDGE AND LEARNING.
by Gabriel D. Ofiesh

There is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all who profit by the old order, and only lukewarm defenders in all those who would profit by the new order. This quality of lukewarmness arises partly from a fear of adversaries, who have the law on their side, and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it.

Machiavelli, "The Prince, "1513

CD/OD ROM is such a dramatic innovation that it requires a completely new way of looking at not only the problems of education and training but the recursive nature of knowledge itself. Through the use of icons and micro-based menus, CD/OD ROM provides knowledge engineers, instructional designers, educators, training directors, and planners with radically new opportunities for designing and adapting training and educational materials to instructional systems-based interactive training formats. CD ROM hasthe capability and technological potential for educators to create a "seamless carpet of knowledge and learning." Several potential scenarios illustrate how the CD/OD ROM can be utilized for exploratory and discovery learning as well as for self-instructional strategies which can radically alter not only education but the very structure of the knowledge on which it is based.

In writing this chapter for "The New Papyrus, "I fully recognize my limitations. I am not an electronics or light engineer. In

tracking the videodisc and the CD ROM I have difficulty in following much of the technical discussions. In spite of these constraints, as an educator and educational technologist there are some suggestions that deserve to be stated which may provide guidance to the instrumentation engineers concerning the potential use of the CD ROM technology beyond that as an archival medium. I do consider myself, however, to be an educational engineer--pejorative as the term "engineering" may be to many of my educator friends. When I established the Center for Educational Technology at The Catholic University of America in 1966, I wrote the first definitive article describing our graduate program as one that trained tomorrow's educational engineers.

Over the past 25 years I have tracked a variety of new technologies of communication that may affect education and training, and I have found that they never really did have an impact on education. Though I have steadily gained an appreciation of the contributions of scientists in the computer and electronic fields, I am not ready to deify them. I admit to a sense of awe in thinking of their many contributions--the creations that come out of the Bell Labs, for example. I do not understand how the microcomputer works--nor will I. Nor do I think I need to know. I have never understood how my car, telephone, or television set works. Yet I have been able to use them and other powerful tools quite successfully. On the other hand, I do recognize, and am fully aware of, the tremendous power inherent in the micro--as well as the videodisc and now the CD and OD ROM.

We have all heard about the knowledge explosion. Explosion is not the proper metaphor. An explosion is a one-time-only affair. What we have is, and will continue to be, a flood of knowledge. I have on my bookshelf three volumes that are replicas of the complete "Encyclopaedia Britannica "as it was published in the year 1771. These three volumes represent the condensed state of knowledge at that time. Today the "Britannica "consists of over 40 volumes. Yet, from reading other articles in this book, you know that today's "Britannica "could not fill a compact disc.

The challenge confronting education and educators today is not to produce more electronic technology but, rather, to develop creatively the educational potential that the current new technologies offer. This requires almost a complete break with the conventional wisdom. We need to think in ways we never thought in the past.

Psychologist Eugene Galenter tells us that the micro will bring about the most profound changes in civilization since the

invention of agriculture. I personally think that the impact will be even more profound. The micro revolution is on the same level as the Copernican revolution.

I hesitate to predict the future. I have no idea what it will be like. A few months ago, in giving a talk, I was introduced as the prophet of the future. I corrected the introduction by saying that I was a prophet of the present. If I have any vision, it is a vision of the present. Recently, Richard Braddock, Citibank/Citicorp's group executive who is responsible for all consumer financial services in the United States, told conferees in an address: "We are living through an exciting and demanding time--one in which our abilities to manage or even cope are being challenged more each day."

He further cautioned, "The future belongs not to the wide-eyed visionaries who speculate on where the technology can go. It belongs to the sharp-eyed realists who determine where the technology "should "go to meet users' unmet demands." No one can really predict the future potential of the new technologies. Even inventors themselves sometimes intend completely different applications for their inventions than what eventually develops with them. Braddock points out that Edison didn't have the slightest idea the phonograph would be used for the reproduction of music or that it would create a new industry--the record business. He believed that the phonograph would have a relatively small market limited to, and I quote,

"Those members of the legal profession who, wishing to eliminate disputation from the settlement of estates, would invite their clients into the office for the direct inscribing of their wishes onto the machine."

In 1876, Alexander Graham Bell presented the telephone to the world, and the world yawned. Historians report that the majority of people of that day saw no obvious application for Bell's invention. The "London Times "called it "the latest American humbug." Western Union, the giant among the new telecommunications agencies of that time, was offered exclusive patent rights to the telephone. Western Union's chairman quickly refused the offer saying, "What use would this company have for an electrical toy?"

Thomas Edison was out to assist lawyers, and Alexander Graham Bell was deeply concerned with the plight of the deaf. Innovations like theirs led to revolutionary changes, but different from what they

foresaw. Once people in search of applications make a breakthrough, then a second creative process starts that puts the new discovery to work in solving an existing problem or accomplishing something new that could not be done before.

The information and telecommunications revolutions are no exception. When the computer came into existence in the 1940s, very few people had the imagination to see how it would be used.

Who would have guessed, 40 years ago, that the rudimentary computer, designed by British experts to break German codes in World War II, would become the impetus creating the gigantic industries of today? Now we find every major industry in the midst of change. While the pace of change has accelerated since Edison and Bell, the same standard still holds. What happened to the phonograph, the telephone, and the computer will happen again: The users will call the shots. Clearly, Edison's phonograph solved the problems he set out to solve, but the market didn't share his view of the application. Rather, his technological breakthrough eventually gave impetus to a brand-new use that captured the minds, hearts and pocketbooks of the general public.

It is the market that is driving the new technologies, not technological forces. And it is market forces that will drive the PC and the CD/OD ROM for the next decade. Forty years ago, in an "Atlantic Monthly "article (reprinted in this book), Vannevar Bush prophetically predicted the information flood produced by the scientific and technological revolutions, and unknowingly foresaw the development of the CD/OD ROM. Bush perceived the practical need as well as the economic necessity for extending scientific developments, recording and storing information, and "*accessing and consulting the record as needed* "(italics mine). At the time he recognized that our publication capability and the expansion of scientific information had extended far beyond our ability to make real use of the record. In practical terms, the methods used until now to transmit and review knowledge and research have been totally inadequate for our needs.

To quote Bush, "*The modern library is not generally consulted, it is nibbled at by a few.*" (I would add the dictionary and thesaurus.) Mere compression of records and information is not enough. Without the ability to consult records spontaneously, humanity will be dogged with the curse of having our greatest inventions lost in a mass of the inconsequential. The promise of the microprocessor, and especially the CD/OD ROM peripheral, is one of the transformation of information. The new technologies have brought us to the point where we can cost-effectively store,

compress, and disseminate information formerly accessible to only a few.

Bush's vintage article, aptly titled "As We May Think," was written when I began teaching my first course in psychology. Bush, then a supervisor of over 1000 scientists, had a prophetic vision of the CD/OD ROM. Let me just quote a few passages from his article:

"There is a growing mountain of research. There is increased evidence that we are being bogged down by that information as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers."

"These are conclusions which he cannot find time to grasp, much less to remember...Yet, specialization becomes increasingly necessary for progress, and the effort to bridge the disciplines is correspondingly superficial."

His words remind me of Alfred North Whitehead's comment that we teach èalgebra from which nothing follows, biology from which nothing follows, chemistry from which nothing follows, and so on. Bush goes on to tell us that, professionally, our methods of transmitting and reviewing the results of research are generations old. By now the methodology is totally inadequate for its purpose.

Many conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading; yet they might well shy away from an examination calculated to show how much of the previous month's efforts could be reproduced on demand. Mendel's understanding of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable of grasping and expanding it. This sort of catastrophe is undoubtedly being repeated all about us, as truly significant attainments become lost in the mass of the inconsequential.

Again, may I remind you I am reading from an article written in 1945. Let me go on:

"The difficulty seems to be that the art of publication has been extended beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through this information maze to reach the momentarily important item is the same as that used in the days of square-rigged ships."

Now listen to this:

" But, there is hope! There are signs of a change as new and powerful instrumentalities come into use. Such as photocells capable of seeing things in a physical sense, advanced photography which can record the seen or even the unseen, thermionic tubes capable of controlling potent forces under the guidance of less power than that used by a mosquito to vibrate his wings, cathode ray tubes rendering visible an occurrence so brief that a microsecond is a long time by comparison, relay combinations which carry out involved sequences of movements more reliably than any human operator and thousands of times faster....These are but a few of the changes. There are plenty of mechanical aids that can be used to effect a transformation in scientific records ..."

In 1945, Bush was telling us that:

"...We now push a pencil or tap a typewriter to make the record. Then, the process of digestion and correction follows and then comes an intricate process of typesetting, printing, and distribution ... Will the author of the future cease writing by hand or typewriter and talk directly to the record? He does so indirectly, by talking to a stenographer transcribing on a wax cylinder; but the elements are all present for him to talk directly into a device that will produce a typed record. He simply needs to take advantage of existing mechanisms and alter his language slightly".

Mind-boggling, isn't it? If Bush could only be around today to tell us what is around the corner!

Bush strikes at the heart of our problems in using our wealth of knowledge when he says:

"..Our ineptitude in getting at the record is largely caused by indexing. When data of any sort is put into storage, it is indexed alphabetically or numerically. Information is retrieved by tracing it down from subclass to subclass. Unless duplicates are made, information can only be stored in one place. Rules govern which path must be followed to locate information; and the rules are cumbersome. Having found one item, moreover, one must emerge from the system and re-enter on a new path to find related information. The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next related item. Suggestion triggers the association of thoughts. Our intricate web of neural trails carried by the cells of the brain makes possible this associative thinking."

And this leads Bush to create a future device that is designed to be a sort of mechanized private file and library. This device he calls a "*memex*," which he defines as a device "*in which an individual stores his books, records,and personalcommunications. It is mechanized so that it may be consulted with exceeding speed and flexibility. It provides an enlarged intimate supplement to his memory ... ."*

Now hear this for the generic scenario:

"..Of course, it will be possible to consult the record by the usual scheme of indexing. If the user wishes to consult a certain book, he can tap its code on the keyboard, and the title page of the book will appear promptly before him, projected onto a screen. Frequently-used codes are mnemonic, so that he seldom will have to consult his code book. When he does, a single tap of a key projects it on the screen for his use. Moreover, he will have supplemental levers. By deflecting another lever he can run through the book before him, each page in turn being projected at a speed which just allows a recognizing glance at each. If he deflects it further to the right, he steps through the book 10 pages at a time; still further, 100 pages at a time. Deflection to the left gives him the same control backwards. A special button transfers him immediately to the first page of the index. Any given book of his library can thus be called up and consulted with far greater facility than if it were taken from a shelf. As he has several projection positions, he can leave one item in position while he calls up another. He can add marginal notes and comments, taking advantage of one possible type of dry photography, and it could even be arranged so that he can do this by a stylus scheme, such as is now employed in the telautograph seen in railroad waiting rooms, just as though he had the physical page before him....

The owner of the memex, let us say, is interested in the origin and properties of the bow and arrow. Specifically he is studying why the short Turkish bow was apparently superior to the English long bow in the skirmishes of the Crusades. He has dozens of possibly pertinent books and articles in his memex. First he runs through an encyclopedia, finds and interesting by sketchy article, leaves it projected. Next, in a history, he finds another pertinent item. When it becomes evident that the elastic properties of available materials had a great deal to do with the bow, he branches off on a side trail which takes him through textbooks on elasticity and tables of physical constants. he inserts a page of longhand analysis of his own. Thus he builds a trail of his interest through the

maze of materials available to him.

....And his trails do not fade. Several years later, his talk with a friend turns to the queer ways in which a people resist innovations, even of vital interest. He has an example, in the fact that the outraged Europeans still failed to adopt the Turkish bow. In fact he has a trail on it. A touch brings up the code book. Tapping a few keys projects the head of the trail. A lever runs through it at will, stopping at interesting items, going off on side excursions. It is an interesting trail, pertinent to the discussion. So he sets a reproducer in action, photographs the whole trail out, and passes it to his friend for insertion in his own memex, there to be linked into the more general trail...."

For a more detailed description of his memex-desk you will have to read his article. If you do, you will have a sense of deja vu.

A Few Scenarios

The Smart Card is in the same family as the CD/OD ROM. It is a portable data storage device with intelligence and provisions for identity and security. At present they are used as bank cards, telephone credit cards, and security ID badges. The intelligence in the card can be readily programmed for different applications without any change in design. The identity and security provisions protect the card's proper owner as well as allowing access to the stored data. The card cannot be used until the bearer upplies the matching code. The memory of the Smart Card is normally programmed to the requirements of a specific application at the time of èissue. The Smart Card's memory is updated each time it is used, and each transaction is recorded on the card. Publishers are currently pursuing applications in which erasibility and/or reprogramming may be appropriate.
This change could have strong implications for learning applications. It s incumbent on the educator, however, to see the applications.

Educational technology is a science which too often has been based on the adaptation of present technological developments to educational purposes rather than on developing technological innovations from learning needs.

When the microcomputer and interactive videodisc were invented, theeducational technologist began to explore its learning applications. The result was computer-assisted instruction (CAI) and interactive training packages used in vocational and technical

education. Now that the Smart Card has come on the scene, the educational technologist is plotting again.

How can the memory of the CD/OD ROM and the Smart Card be programmed to identify a student and access instructional material at his or her appropriate and changing developmental level? Can the Smart Card be used to test cognitive development and then supply appropriate assignments of homework--much as it now computes financial transactions and reads out the new balance in a checking account? In this day of individualized instruction, can a student's identity card take the student into a teaching dimension tailored to his specific learning needs through a method of menus that branch out to knowledge units tied directly or indirectly to other sequential knowledge units?

Can the CD/OD ROM and the Smart Card become a major tool in making the learning environment truly adaptive to the idiosyncratic needs of the learner? These are the questions educational technologists must ask those who design the new technologies. But our needs have to be known to the engineer early in the design process. It is up to the educational technologists to come up with the scenarios and applications, to break down and adapt to the machine capabilities of the units of knowledge in different subject and skill areas.

These are the challenges which the instrumentation or delivery-system technologists have placed before us as educators. We can now write the scenarios we always dreamed of writing. We can compose just about any stimulus configuration for any type of learning and corresponding response configuration.

As educators, we need to be engaged directly with the CD/OD ROM. Only then can we begin to appreciate what this powerful computer peripheral can and cannot do. Only then can we learn what is easy to do, and what may be cumbersome today but easy tomorrow. In short, we need to begin to join forces with the makers of the tool in tackling the tasks we must accomplish. A good starting point for our exploratory application efforts is the Grolier disc. And if, as they say, the Grolier disc will soon contain not only the encyclopedia but a dictionary and thesaurus as well, then we need to start using it, and from our trial and error efforts provide the scenarios and suggestions for the third and fourth editions!

Then, in the words of Stephan Haeckel of IBM, we may graduate into a new way of thinking. If the technology--be it the PC or CD/OD ROM or Smart Card or a combination of all--can do these things, perhaps that same capability can be applied to other related

educational problems. Finally, some day we as educators, will come of age technologically. We will be able to move about freely, utilizing the computer's extensive memory banks èand capabilities with ease.

The micro wedded to the CD/OD ROM has the inherent ability to extend our personal vision. Few of today's applications were conceivable just 20 years ago--or even 5 years ago. We are experiencing an exponential (constantly accelerating) rate of change. The computer can extend the range of our senses and enlarge our supply of concepts. The ability to integrate, synthesize, and enhance information from a large number of sources puts us as learners in a position similar to the astronaut about to pull away from the gravitational hold of earth.

Alfred North Whitehead would have envied us our opportunities. The human imagination can revel in new contexts and identify and follow new patterns of thought formerly unavailable. Through these new technologies we can learn to think thoughts we otherwise could never have imagined.

It should not be surprising that the new technologies such as CD/OD ROM and the Smart Card can go in directions in the next decade that are difficult to project. We educators need to turn to those furthest along on the computer learning curve for some guidance. We need to observe creative talents, such as those at MIT's Center for Arts and Media Technology, where exploratory efforts include computer music, personalized electronic newspapers, and interactive movies. The work is seminal and only visionary for some, even though it is firmly based on state-of-the-art technology.

Like any change, the introduction of technology must be managed and led into uncharted areas if it is to radically change the face of education. It is time for some of us in education to lead the technology rather than to be led by it. If we are up to the task, then the next decade will be rewarding and creative in terms of combined technologies, applications, and needs--bringing education to a level we have never before dared contemplate. In order to provide for this leadership, we as educators need to develop some scenarios and let the delivery-systems engineers put the support pieces together.

Scenario One

A few days ago I was reading an article by William J. Broad in the Science section of the "New York Times "(22 November 1985). The article was titled "Light May Be Key to New Generation of Fast Computers." Here are some passages from the article:

All computers, be they personal ones or government behemoths, rely on digital switching by streams of electrons. Today, however, a few bold scientists believe they are on the verge of a radical change in the fundamentals of the field. They envision computers that run on light instead of electricity. Though there are skeptics who believe it impossible, the goal of these scientists is to abandon electrons altogether for the tiny packets of light known as photons. The attraction is that photonic computers could work thousands of times faster than the best possible electronic ones, and could process data in remarkable new ways.

"*The key to the future is to go from electrons to photons*," said Dr. Rustum Roy, professor of solid-state science at ennsylvania State University and past director of the university's Materials Research Laboratory.

Let me stop here for a moment.

What kind of questions go through my mind as I read this? Let me remind you that the "New York Times "Science section is written for the literate lay reader. The scientist would ask for the technical papers. I consider myself to be one of these literate laymen. I do not fully understand, however, what "digital switching by streams of electrons" is. But I do have a hazy idea of what it is. Let us imagine that this edition of the "Times "is on a CD ROM disc and that the computer reading the disc has the following colored squares: red for definition, blue for graphics and/or pictures, green for clarification, yellow for remedial learning sequence, orange for animation, black for voice synthesis, and soon.

Further, let us imagine that I could elicit any of these by touching the colored icon on the screen or using a mouse--or even calling out the color. But wouldn't it be nice if I could touch the blue and/or orange icon on the screen with the cursor flashing under the phrase "digital switching by streams of electrons" and immediately get a dynamic visual graphic--and possibly holographic--explanation of the concept!

Another need for a horizontal deviation from a linear reading of the article is illustrated by the quotation "the goals of these scientists is to abandon electrons altogether for the tiny packets of light known as photons."

One has to stop and ask, "OK, what is a photon?" Do you know? Have you ever seen a diagram of one? For some, the photon may be a completely new concept. In fact, this was the first time I had read anything about a photon. One of my associates, with whom I was discussing this article during its draft stages, was shocked at my ignorance. She asked, "Don't you know about photosynthesis?" in a tone of voice which implied that "everyone "knows about photosynthesis. What she didn't know was that I had never taken a course in botany; I took French Literature instead.

I'd like to know what it is now--not three pages or three years later. As the cursor is flashing under the word "photon "I would like to be able to touch a red icon, which would stand for the definition, and get the dictionary explanation of photon. Or I would want to touch the blue icon, which would give me the "Encyclopaedia Britannica "definition of a photon; or the yellow icon, which would give me a visual picture of the definition accompanied by a remedial learning sequence.

I think that Vannevar Bush would appreciate this.

Now, let me continue with the "Times "article.

"It's like trying to conquer Mount Everest," said Dr. Alan Huang, director of the newly formed Optical Computing Department at AT&T Bell Laboratories. "We're doing something with a lot of risk. We're taking the first step on a journey of 1,000 miles." Despite this seemingly enormous challenge, Dr. Huang believes his Bell Labs team can create, within just one year, a primitive prototype of an optical computer and, within five years, a working full-scale model. "A real number-cruncher," as he put it. "Number-cruncher?" What is that?

I keep hearing it everywhere I turn today. Recently I was able to grasp its meaning when someone explained to me that "number-crunching" referred to the ability to process millions and millions of computer operations a second.

Dr. Huang quickly added that "Bell Labs has a reputation for innovations, having invented the transistor, the maser, the laser and many devices that have advanced the art of manipulating light

to man's advantage."

The term "maser" is completely new to me. So I touch another icon and I receive an animated and graphic description of the maser.

To continue with the article:

The key is to create an optical analog of the transistor, which is still the muscle behind computation. It would switch light on and off in a way similar to how a transistor switches electricity.

Here I may stop and wonder what exactly a transistor is and what its importance is to computing. I would like to be able to push an icon and have this concept clarified for me.

You get my point: If I could have spontaneous access to other references and sources of information, I would start to come close to the "seamless carpet of learning" that I mentioned earlier.

Now we are talking about interactivity in learning in a way we never talked about it before. Exploratory and discovery learning? There are no frames or boundaries anymore.

There are other technologies similar to the CD ROM that are exploring the possibilities embedded in the above scenario. For example, in August 1985, Xerox introduced Notecards. Frank G. Halasz, a research scientist at the Xerox Corporation's Palo Alto Research Center and project director for the Notecard, says that the Notecard can "*provide a document that people can look at at various levels."*

Andrew Pollack, writing in the "New York Times "recently (29 August 1985), tells us of the constraints and limitations of text written on paper. He points out that text written on paper must be in a specific order. Because articles "*have a particular order of paragraphs the reader will normally follow from beginning to end in sequential fashion."* To my mind this limits creative thinking while reading. The "*grasshopper mentality*" finds it difficult to deal with printed materials.

Pollack suggests that "c*omputer-based information need not be bound by such restrictions imposed by paper. With computers it is possible to have individual small packets of information that can be called up in any order the reader desires. The concept has been called nonsequential text, or hypertext, and it is slowly gaining adherents in computer science.*"

Well, what Pollack is really talking about is not only

computer-based information but also the media that make it possible: CD ROM, the Smart Card, and the new Xerox Notecard.

Pollack illustrates the potential activities of hypertext by describing what I have chosen to call the "grasshopper mentality." The concept is not easy to grasp, but one analogy might be a variety of tours through a museum.

Some provide a single route that takes a visitor past all the exhibits. Others concentrate on certain exhibits and by-pass others. Similarly, an electronic hypertext document would offer choices. For instance, a person reading a hypertext article about a company would have a choice of how much detail he wanted on the company's history and how much on finances. The concepts have been in some electronic novels--and computer games--in which the plot changes depending on choices made by the player.

But hypertext would also allow users to link different documents. Encyclopedias, for instance, often contain cross references to other articles, which in turn contain cross references to still others. But following the cross references is tedious. With a hypertext encyclopedia, a reader could press a button and jump to the relevant part of the cross-referenced article and from there to another cross-referenced article. In short, one could hop from article to article, following a given idea.

Similarly, instead of just seeing a reference to another book in a footnote, a reader could move immediately to the relevant part of that book. Traditional data banks permit the retrieval of documents quickly but do not allow movement from one document to the middle of another.

The first hypertext system was developed in the early 1960s by Douglas C. Engelbart. He also developed the mouse for controlling the computer. Ted Nelson, an author and futurist, coined the term "hypertext" in the mid-sixties. At Brown University, a hypertext system using the Macintosh computer, will be tested in an English course as a way of providing students with information and comments on the literature being read.
Simple concepts related to hypertext are appearing in personal computer programs such as Thinktank by Living Videotext Inc., and Framework by Ashton-Tate. These programs, sometimes called outline processors or idea processors, allow users to manipulate blocks of data into outline form.

With Notecards, however, ideas do not have to be organized into a linear outline. The system allows any card to be connected to any other in a complex network. One can envision the system as

consisting of cards with lines between them, like a map of cities and the roads between them.

Scenario Two

Recently, I have been fascinated by artificial intelligence genius Douglas Hofstadter's Metamagical Themas. Likewise impressed, Leonard Bernstein writes:

> *Doug Hofstadter is rapidly becoming the Hamlet of our times: whatever he says is both exact and double-edged, reassuring but provocative, poetic and self-challenging. His scariest insights and most agonizing intellectual probings are graced, like Hamlet's, with humor, affection, and a kind of mad musical charm.*

Martin Gardner writes:

> *[Douglas Hofstadter] is as incapable of writing opaquely as his alter- ego Egbert B. Gebstadter is incapable of writing clearly. Like his previous "Godel, Escher, Bach: An Eternal Golden Braid, "the new book glitters with Godelian self-reference jokes, Escherlike illustrations, and Bachlike fugues.*

According to Daniel C. Dennett, Professor of Philosophy at Tufts University:

> *This wonderful collection tackles virtually every area of fascination and controversy in science today, from mathematics and quantum mechanics through evolutionary theory to artificial intelligence, the nature of human thought and rational choice, and ties them together by showing how understanding in one area enhances understanding in others. Hofstadter realizes that before you can "prove" or "refute" anything, you must "understand."*

The challenge confronting me as a reader was how to get understanding in one area before I could have an enhancement of understanding in another area. These comments intrigued me. I said to myself, "This is a book that I must read." So I purchased a copy and read the blurb. Let me just relate to you a few paragraphs from the blurb, which will give you some idea of why I realized very shortly that I could not possibly master the book until I had read his earlier treatise, "Godel, Escher, Bach: An Eternal Golden Braid, "subtitled "A Metaphorical Fugue on Minds and Machines in the Spirit of Lewis Carroll.

Even the blurb, let alone the book, should have been on a CD ROM allowing me to find definitions and clarifications for some of the terms used.

For example,

> *In this scholarly, entertaining, and provocative book named after his recent column in "Scientific American, "Douglas Hofstadter has collected 33 essays and woven them together with elaborate postscripts. All "Metamagical Themas" columns are included, as well as seven other pieces. Despite its wide range of topics, "Metamagical Themes "possesses a strong sense of unity, thanks to the author's painstaking efforts, in the postscripts, to spell out connections, cross-references, and implicit ideas.*

So far, no problem.

> The primary concern, permeating virtually every page, is how people perceive and think. Hofstadter explores the fluidity of human analogical thought and perception, along with strategies for making machines that perceive, create, and feel. His essays range from self-describing sentences in French to sexist language in Chinese; from a sober condemnation of public "innumeracy" to an enthusiastic soliloquy on the infinite richness of the alphabet; from genetic evolution to its software counterpart, "mimetic" evolution; from experiments with the Prisoner's Dilemma to the beautiful mathematical shapes known as "strange attractors"; from quantum-mechanical quarks to Rubik's cubical quarks. Hofstadter asks how musical and visual patterns can stir our emotions; how we manage to sift the true from the false, the relevant from the irrelevant, the meaningful from the meaningless.

Now that paragraph took some thought, and the dictionary was not of much help. Let me list my problem areas:

o Sober condemnation of public "innumeracy"

o "Mimetic" evolution

o Beautiful mathematical shapes known as "strange attractors"

o Quantum-mechanical quarks

o Rubik's-cubical quarks

Well, I didn't want to give up. So then I went to "Godel, Escher, and Bach. "Let us imagine that I not only have the book on the CD ROM but also all the ancillary references.

For example, here is the first paragraph:

> *Bach Frederick was an admirer not only of pianos, but also of an organist and composer by the name of J. S. Bach. This Bach's compositions were somewhat notorious. Some called them "turgid and confused," while others claimed they were incomparable masterpieces. But no one disputed Bach's ability to improvise on the organ. In those days, being an organist not only meant being able to play, but also to extemporize, and Bach was known far and wide for his remarkable extemporizations. (For some delightful anecdotes about Bach's extemporization, see "The Bach Reader, "by H. T. David and A. Mendel.)*

Now, that interests me. I would like to see "The Bach Reader. "But where do I find it? I assure you it is not on my library shelf. The Library of Congress? My favorite bookstore? Oh, well, I say to myself--nice thought.

But the delightful anecdotes about Bach's extemporization will have to wait for another time. Or be forgotten. A learning opportunity lost. But if Hofstadter had made arrangements with his CD ROM publisher to include all his references, then all I would have to do is touch an icon and immediately access "The Bach Reader "and enjoy the delightful anecdotes about Bach's extemporizations.

Presently, in reading--no, not reading, studying really--"Godel, Escher, and Bach, "I am using the services of three consultants. I cannot read music, so I call up and ask my good friend Dr. X, a psychologist, system theorist, musical composer, and concert pianist for guidance. I know something about mathematics, but I'm not that good; so here I need the services of another colleague, a professor of mathematics, to help me with Godel. With respect to Escher, the text is well illustrated, and with the help of an art

historian, I receive further assistance. But what a laborious task this is. And to gather these minds together at, say, two o'clock in the morning, if I choose to read at that hour, or at any time convenient to all of us is virtually impossible.

With a multimedia CD ROM and the icons described above, I could handle the following potpourri of paragraphs and sentences with ease and delight. Who knows? Education may truly become ecstacy.

Back to the text :

> *To give an idea of how extraordinary a six-part fugue is, in the entire "Well-Tempered Clavier "by Bach, containing forty-eight preludes and fugues, only two have as many as five parts, and nowhere is there a six-part fugue! One could probably liken the task of improvising a six-part fugue to the playing of sixty simultaneous blindfold games of chess, and winning them all. To improvise an eight-part fugue is really beyond human capability. In the copy which Bach sent to King Frederick, on the page preceding the first sheet of music, was the following inscription:*
>
> *Regis Iusfu Cantio et Reliqua Canonica Arte Refolula*

Touching several icons, I have an explanation of a six-part fugue in both sound and graphics. Another icon gives me the translation of the Latin inscription.

Let me take you to another section. Where Hofstadter asks us to:

> Look, for example, at the lithograph "Waterfall, "and compare its six-step endlessly falling loop with the six-step endlessly rising loop of the "Canon per Tonos. "The similarity of vision is remarkable. Bach and Escher are playing one single theme in two different "keys": music and art ... Escher realized Strange Loops in several different ways, and they can be arranged according to the tightness of the loop. The lithograph "Ascending and Descending, "in which monks trudge

> forever in loops, is the loosest version, since it involves so many steps before the starting point is regained. A tighter loop is contained in "Waterfall, "which, as we already observed, involves only six discrete steps. You may be thinking that there is some ambiguity in the notion of a single "step"--for instance, couldn't "Ascending and Descending "be seen just as easily as having four levels (staircases) as forty-five levels (stairs)? It is indeed true that there is an inherent haziness in level-counting, not only in Escher pictures, but in hierarchical, many-level systems. We will sharpen our understanding of this haziness later on. But let us not get too distracted now! As we tighten our loop, we come to the remarkable "Drawing Hands, "in which each of two hands draws the other: a two-step Strange Loop. And finally, the tightest of all Strange Loops is realized in "Print Gallery: "a picture of a picture which contains itself. Or is it a picture of a gallery which contains itself? Or of a town which contains itself? Or a young man who contains himself? (Incidentally, the illusion underlying "Ascending and Descending "and "Waterfall "was not invented by Escher, but by Roger Penrose, a British mathematician, in 1958. However, the theme of the Strange Loop was already present in Escher's work in 1948, the year he drew "Drawing Hands. Print Gallery "dates from 1956.)

At this point, if you are the average literate reader, as I presume I am, I know that I cannot have a firm grasp of Strange Loops without some help from my consultants, and even with their help I would still have difficulty with understanding Epimenides' paradox that Hofstadter tries to explain when he gets to Godel. The print medium makes it extremely difficult to deal with recursive concepts. I am convinced that the capabilities of the CD ROM, powered by the micro, can make the reading of Hofstadter's genius a truly delightful and exploratory experience--rather than the laborious, painstaking effort it has been to date. Hofstadter is attempting to communicate his genius in a constrained format. He needs the tools of a composer; and in his book he is also dealing with mathematics, philosophy,
and art.

Eventually, this kind of knowledge must come about through discovery learning, not through the sequential acquisition of ideas. We are now to the point where we can look at knowledge bases and learning with "no frames and no boundaries."

The micro can become the most civilizing influence that we have

had to date. It can amplify our intelligence and our ability to manipulate symbols. Pamela McCorduck, in her book "The Universal Machine, "traces the long intellectual tradition that began with the human language itself and encompasses the Golden Age of Greece, the burghers of fifteenth-century northern Europe, and America's own Henry Adams. On a personal search for a bridge between C. P. Snow's Two Cultures--the humanities and the sciences--she sees the computer as the bridge, the machine of the century, the hope of the future. I agree completely. She asks, "What shall we call electronic text?" But she never really answers the question, leaving it to our imagination instead.

We are finding little in the way of answers, but much in the way of questions. We are just beginning to scratch the surface of this powerful new technology. It can give us a new way of thinking about knowledge itself and help us to explore completely new possibilities in learning. I cannot help recalling the words of the late Russell Schwikert, an Apollo IX astronaut, who, as he was circling the earth and looking down at the small sphere we call our global village, was heard to say:

> When you go around it in an hour and a half, you begin to recognize that your identity is with that whole thing. And that makes a change.
>
> You look down there, and you can't imagine how many borders and boundaries you cross, again and again and again, and you don't even see them. There you are--hundreds of people killing each other over some imaginary line that you're not even aware of, that you can't see. From where you see it, the thing is a whole, and it's so beautiful. You wish you could take one person in each hand and say, "Look at it from this perspective. What's important?"
>
> You realize that on that small spot, that little blue and white thing, is everything that means anything to you. All of history and music and poetry and art and birth and love; tears, joy, games. All of it on that little spot out there that you can cover with your thumb.

That "little spot" contains so much. The little micro--and the little chip and the little compact disc--can also contain so much.

There is no question in my mind that compact disc technology will be prevalent throughout the world. It can contain everything that we have been, and are, and are going to be. Compact disc players and compact discs will entertain people throughout this global village of ours. Whether its educational potential will be realized remains to be seen. It is possible, but not likely, if history provides any lessons, that educators will work with electronic and light engineers to break with the past and achieve and embark on new paths of learning. Those of you who watched the Live Aid Concert in July 1985 may recall the Soviet announcer who exclaimed that "it's nice that high technology is contributing to something positive."

Walter J. Bojsza, New Products Editor of "Electronics Design, "reminds us that the Live Aid broadcast was a marvel of the technically impossible made commonplace. It was beamed to 152 countries around the world through 14 satellites. The stadiums of London and Philadelphia were linked electronically with a clarity hardly possible at times in the same building. Digital circuits reconciled American and European transmission standards to produce intricate visual animated graphics. All these systems worked so smoothly that they were virtually transparent.

If we start talking about CD ROM-assisted learning in the same way in which we talk about computer-assisted instruction, then we will fall far short of the goal. We do not talk about pencil-based learning or book-based learning, and I fail to understand why it is that we talk about computer-assisted learning. Only when these new tools become virtually as transparent as the book and the newspaper and the TV set will we really begin to exploit them. And for this task, we need systems designers who will listen to the poets of education, and for the poets to respect the systems engineers. Both of us need to dream together.

About forty years ago I attended a meeting of the American Psychological Association, where B. F. Skinner was asked by a young graduate student what he thought of Jerome Bruner's astonishing dictum that you can teach anything to anyone in an intellectually honest manner at any age level whatsoever. Skinner simply shrugged his shoulders and said, "How?"

I merely would like to add that while Skinner and Bruner were writing and speaking, Vannevar Bush was penning his "Atlantic "article. Forty years later, all three minds meet. With the micro-powered CD ROM containing the necessary software, we are now able to answer Professor Skinner's "how?" and make Bruner's dream a reality.

The late Robert Kennedy unwittingly quoted George Bernard Shaw, who in turn had unwittingly quoted Aeschylus, as all three said, "Some people look at things that are and ask, 'Why?' I look at things that never were and ask, 'Why not?"'

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